Ultra-Wideband Time-Difference-Of-Arrival Two-Point-Tracking System

Jianjun (David) Ni, *Johnson Space Center*
Dickey Arndt, *Johnson Space Center*
Phong Ngo, *Johnson Space Center*
Chau Phan, *Johnson Space Center*
Kent Dekome, *Johnson Space Center*
John Dusl, *Johnson Space Center*

This report briefly discusses a design effort for a prototype Ultra-Wideband (UWB) Time-Difference-of-Arrival (TDOA) Two-Point-Tracking System that is currently under development at NASA Johnson Space Center (JSC). The system is being designed for use in assisting a docking process in a two-dimensional (2-D) space; e.g., the lunar rover Chariot docking to its battery charging station. The UWB Systems Group at JSC has developed a UWB TDOA High-Resolution Proximity Tracking System, which can achieve sub-inch tracking accuracy of a target. A two-point-tracking system is designed to enable aligning a vehicle docking into its station in a 2-D space by using this high-resolution tracking capability.

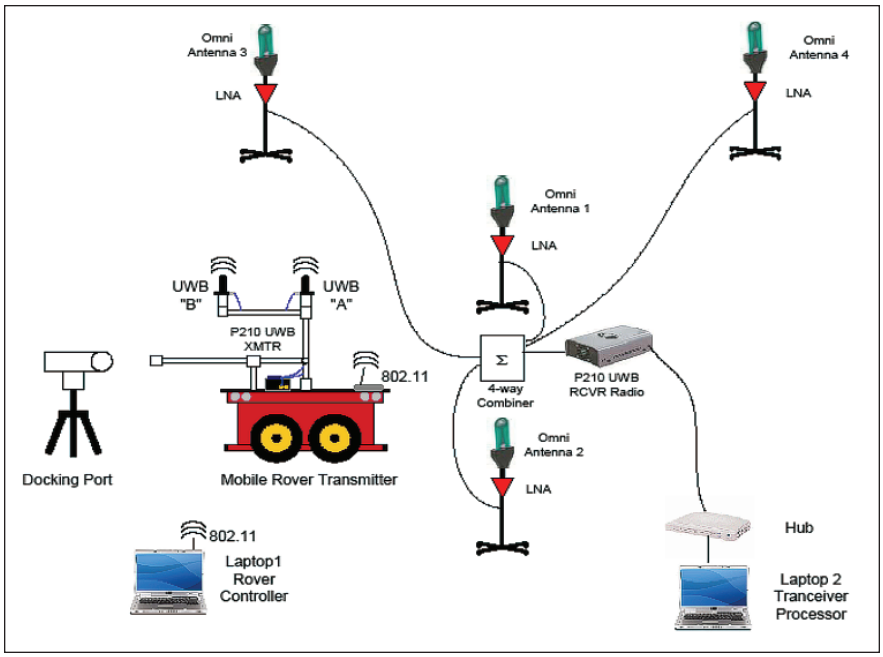

Fig 1. *Baseline configuration of integrated Ultra-Wideband Tracking and Communication System.*

System Design

To dock a vehicle in a 2-D space, the controller needs the location information of at least two points of the vehicle. With that two-point information, the vehicle can be aligned with the planned docking trajectory. For this prototype design, one point (Primary Point) is chosen at the center of the vehicle and another point (Secondary Point) is chosen 0.3 m (1 ft) apart from the center at the front of the vehicle. Primary Point aligns with Secondary Point along the center line. The system configuration is illustrated in figure 1. On the vehicle, one UWB P210 transmitting radio is connected with two antennas through a two-way power splitter. Antenna "A" represents Primary Point and antenna "B" represents Secondary Point. Antenna "B" has a cable delay of about 5 nanoseconds (ns) compared to antenna "A." The vehicle is controlled through an 802.11 wireless link. On the receiving side, a one-radio, four-antenna configuration is used to eliminate the synchronization issue among receivers. Four receiving antennas are connected to one UWB radio receiver through a power combiner.

Performance Analysis

When the transmitter radio on the vehicle transmits one signal, two versions of the same signal are transmitted through two transmitting antennas. Due to the cable delay added to Antenna "B" being greater than the spatial delay between Antenna "A" and Antenna "B," the received signal from Secondary Point is delayed (from 4 ns to 6 ns, depending on the vehicle orientation) and will show up after the Primary Point signal (figure 2). In one scan window, there are four pairs of signals (one pair consists of a Primary Point signal and a Secondary Point signal). A TDOA tracking algorithm is adopted to avoid the synchronization between transmitter and receiver. A signal processing technique—Cross-Correlation plus Peak-Detection—is developed to enable robust TDOA estimate in a noisy multipath environment. With some minor modification of this TDOA estimation algorithm, the positions of the Primary Point and the Secondary Point can be tracked within sub-inch accuracy.

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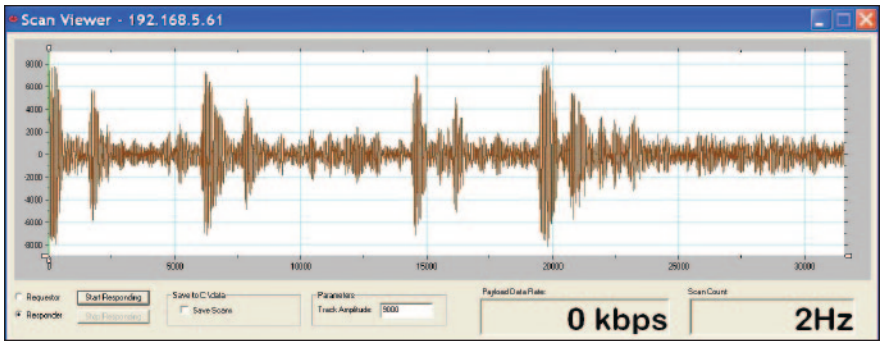

Fig. 2. *Four pairs of signals in one scan window.*

Laboratory Test

The test of the two-point-tracking prototype system has been conducted in the Building 14 High Bay area at JSC. The tests show that the system can track both the Primary Point and the Secondary Point of the vehicle accurately (errors are less than one inch). The controller can use this information to successfully guide the vehicle into its docking station (figure 3) in a 2-D space.

Conclusion

A prototype UWB TDOA two-point-tracking system has been designed, implemented, tested, and proven feasible for docking applications in a 2-D space. Future work includes expanding the tracking area to the size of Chariot docking site and testing the docking process with the actual dimension of the Chariot battery charging station.

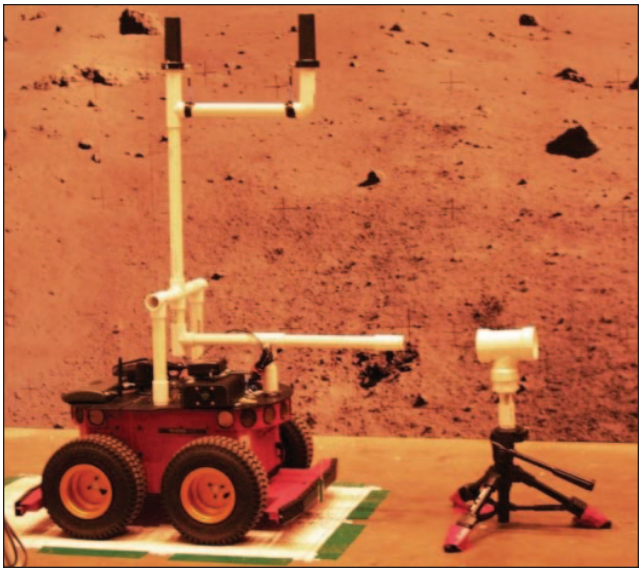

Fig. 3. *Docking process guided by two-point-tracking.*